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THE EFFECT OF SURFACE ROUGHNESS ON TENSILE STRENGTH OF FIBERGLASS REINFORCED POLYMER COMPOSITE

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THE EFFECT OF SURFACE ROUGHNESS ON TENSILE STRENGTH OF FIBERGLASS REINFORCED POLYMER COMPOSITE

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A thesis submitted in fulfilment of the requirements for the
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2019

DECLARATION

I declare that this thesis entitled "The Effect of Surface Roughness on Tensile Strength of Fiberglass Reinforced Polymer Composite" is the result of my own research except as cited in the references. The thesis has not been accepted for any Master and is not concurrently submitted in candidature of any other Master.

Signature	:	
Name	:	Muhammad Najib bin Ibrahim
Date	:	10th June 2019

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Thought Course

Signature :

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Date : 10th June 2019

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DEDICATION

This study is wholeheartedly dedicated to my beloved parents, who have been my source of inspiration and gave me strength when I thought of giving up, who continually provide their moral, spiritual, emotional, and financial support.

To my brothers, sisters, relatives, mentor, friends, and classmates who shared their words of advice and encouragement to finish this study.

And lastly, I dedicated this book to the Almighty God, thank you for the guidance, strength, power of mind, protection and skills and for giving me a healthy life.

ABSTRACT

In composites manufacturing, the surface roughness of the glass fiber reinforced polymer (GFRP) exhibit significant parameter on the mechanical properties of the composite. Thus, in this study, the relationship between the surface roughness and tensile strength due to slip is evaluated. The composite was fabricated by using combination of vacuum compression followed by curing in the autoclave. Set of fiberglass are prepared with different grit size at 400, 600 and 800 at the tab region were tested using tensile test. The parameter is varied by repeating each set of the fiberglass with different frequency of sanding at four (4), eight (8) and twelve (12) times. The effect of the surface roughness using different grit size is analysed using the value tensile strength obtained along with the image produced from optical microscope. At the end of the report, it is expected to obtain optimum surface roughness produced by the grit and the correlation with tensile strength obtained from the tensile testing.

ABSTRAK

Dalam pembuatan komposit, kekasaran permukaan polimer bertetulang gentian kaca (GFRP) mempamerkan parameter penting pada sifat mekanik komposit. Oleh itu, dalam kajian ini, terdapat hubungan antara kekasaran permukaan dan kekuatan tegangan akibat slip dinilai. Komposit dibuat dengan menggunakan gabungan pemampatan vakum diikuti dengan menyembuhkan dalam autoklaf. Set gentian kaca disediakan dengan saiz grit berbeza pada 400, 600 dan 800 di rantau tab yang diuji menggunakan ujian tegangan. Parameter ini bervariasi dengan mengulangi setiap set gentian kaca dengan frekuensi pengamplasan yang berbeza pada empat (4), lapan (8) dan dua belas (12) kali. Kesan kekasaran permukaan menggunakan saiz grit yang berbeza dianalisis menggunakan kekuatan tegangan nilai yang diperolehi bersama dengan imej yang dihasilkan dari mikroskop optik. Di akhir laporan, ia dijangka memperoleh kekasaran permukaan optimum yang dihasilkan oleh grit yang mengaitkannya dengan kekuatan tegangan yang diperoleh dari ujian tegangan.

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CHAPTER 1

INTRODUCTION

1.1 Background

In the world of composites, tensile testing is a common test that being chosen. This testing is used to measure mechanical properties and to predict their behavior of a material under tensile stress and strain. In Composite Technology Research Malaysia (CTRM), tensile test is crucial to ensure that materials and component that being fabricated in the company is within the requirement of as indicated by the supplier as well as customer.

Often there are many variables involved in the fabrication process of glass fiber that could influence the outcome of the materials properties. Glass fibers have been employed in various forms such as longitudinal, woven mat, chopped fiber (distinct) and chopped mats to enhance the mechanical and properties of the fiber reinforced composites. Thus, the initial stage of in-house compression testing is to ensure that performance of the materials is within the claimed condition. The second parameters that might influence the performance of component is their fabrication. Parameters such as surface roughness, autoclave's time, etc. could alter their mechanical properties. Thus, the in-house tensile testing is carried out to ensure that any variability in process is under control and within the production line specification.

1.2 Problem Statement

In CTRM, there are two processes that are required for testing: Incoming receipt testing/ Acceptance testing (IRT) and In-process testing (IPT). Incoming receipt testing (IRT) is a type of testing that to ensure material received from supplier is in good quality and meet customer requirement. IRT is perform in sampling by taking a small portion from the original roll container to do physical and mechanical testing. In-process testing (IPT) is a fabricated sample that represent the respective material or process undergoing.

This project is focus on the IRT process where the material are received from supplier shall undergo quality check by performing several testing including tensile test. This test will evaluate the strength in fiberglass composite which need to fullfill the standard baseline of the testing required. However, this strength was reported to be influenced by the sample preparation and quality of the surface tab area (Caton et al., 2013). The result obtained from the testing is seldom differ from the baseline value which has been outlined by customer. The differ value suspected due to the level surface roughness at the tab area which hold the sample before testing. Surface roughness is a major problem during the production process and greatly affects the quality of the product (Caton et al., 2013). This tensile test problem face by CTRM as the test results did not meet average testing requirement and acceptable failure region mode.

In order to increase competitiveness in cost and quality, these distortions need to be examined and analyzed. As the problem occur, CTRM need to retest the tested sample which undergo slipping as the result were not significant to be reported to the customer and further increase the lead time of the production. Therefore, it is recommended to analyze the initial surface roughness by using sanders and gripper meshes and how it is corresponding to the test result obtain from the tensile test.

1.3 Objective

The objectives of this research are as follows:

i. To investigate the effect of different grit on tensile properties of fibreglass composite using tensile test.

ii. To evaluate the surface roughness of fibreglass composite produced by different grit using surface roughness tester.

iii. To analyze the effect of grit on the microstructure surface fibreglass composite using optical microscopy.

1.4 Scope of Project

The purpose of the project is to investigate the main contribution to the tensile testing failure. This project will involve: evaluate the processing parameter (sample surface roughness, micro section for failure analysis), physical analysis using mechanical testing using tensile testing and analysis of tensile strength and secant modulus of the glass fiber.

1.5 Research Planning

This project Gantt chart is designed to ensure the project accomplishment due to the given time. The activities will set orderly followed by the month to finish each of the activities. By making this, it will work as a guideline to the report progress and assist the project to be finished at the right time. Research planning can be found at appendix 1.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In recent years, composite materials have evolved from an available alternative to most sought-after candidate as structural material in high performance aircraft applications. In comparison to metal, composite has many advantages as they possess higher fatigue strength, higher corrosion resistance and lower weight (Schwartz, 1997; Bakelet al., 2002; Liu et al, 2017). However, the aircraft components fabricated in polymeric composites present tight requirements in service and they can suffer mechanical damages during the utilization (Ding et al., 1995).

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. The two constituents are reinforcement and a matrix. The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. And usually based made of fiber or particulate. A fiber has a length that is much greater than its diameter. Campbell (2010) state that the length-to-diameter (*l*/*d*) ratio is known as the aspect ratio and can vary greatly.

Typical fibers include glass, aramid, and carbon, which may be continuous or discontinuous. Continuous fibers include unidirectional, woven cloth, and helical winding have long aspect ratios, while discontinuous fibers for example chopped fibers and random mat have short aspect ratios. Continuous-fiber composites normally have a preferred orientation, while discontinuous fibers generally have a random orientation.

The strength of discontinuous-fiber composites can approach that of continuous-fiber composites if their aspect ratios are great enough and they are aligned, but it is difficult in practice to maintain good alignment with discontinuous fibers. Discontinuous-fiber composites are normally somewhat random in alignment, which dramatically reduces their strength and modulus. Therefore, continuous-fiber composites are used where higher strength and stiffness are required, and discontinuous-fiber composites are used where cost is the main driver and strength and stiffness are less important (Campbell, 2010). Continuous fibers are of three types according to direction of fibers which are Longitudinal or Uni-directional, Transverse or Bidirectional and Cross or Multi-directional.

2.2 Unidirectional glass fiber

Unidirectional tapes (fiber) have been the standard within the aerospace industry for many years, and the fiber is typically impregnated with thermosetting resins. Fiber glass has a white color and is available as a dry fiber fabric. There are four major types of glass fiber used for composites, as shown from Table 2.1.

Table 2.1: Glass Fiber and Characteristic (Amit, 2014)

Type of Glass Fiber	Characteristics
E-Glass	Good strength & electrical resistivity
S-Glass	40% higher strength, better retention of properties at elevated temperatures
C-Glass	Corrosion resistant
Quartz	Low dielectric properties

The fibers are held in place by the resin. Fiber products have high strength in the fiber direction and virtually no strength across the fibers. Nikhil (2014) has reported that the glass fibers which are used in aerospace sector are based on reinforcing fibers and matrix resins and corresponding to their strength and modulus in Table 2.2.

Table 2.2: Reinforcing Fibers commonly use in Aerospace applications (Nikhil, 2014)

Fiber	Density (g/cc)	Modulus (GPa)	Strength (GPa)	Application areas
E-Glass	2.55	65-75	2.2-2.6	Small passenger a/c parts, air craft interiors, radomes
S-Glass	2.47	85-95	4.4-4.8	Highly loaded parts in passenger a/c

Glass fiber has low performance compared carbon fiber, however from the Table 2.3 show the value of the compression strength is 300 MPa higher than glare and caral. High performance carbon fiber has comparatively high modulus, strength and cost (Botelho et al, 2006).

Table 2.3: Compressive Behaviors of the Specimen (Botelho et al, 2006)

No	**Specimen**	**σ (MPa)**	**Strain (%)**
1	Carbon fiber/epoxy	390 ±24	25.1 ±0.6
2	Glass fiber/epoxy	330 ±26	25.1 ±0.9
3	Glare	310 ±16	19.9 ±1.2
4	Caral	319 ±12	22.5 ±0.3

In comparison of mechanical behavior of epoxy composite reinforced by unidirectional and woven fiber, the experiment was conducted by Eksi S. and Genel K., (2016). Mechanical properties of fiber reinforced composites obtained from tests are given in Table 2.4 while the tensile strength ratios of unidirectional fiber reinforced epoxy composites are given in Table 2.5 experimentally.

Table 2.4: Mechanical properties of Fiber Reinforced Composites obtained from tension, compression and shear tests (Eksi S. and Genel K., 2016)

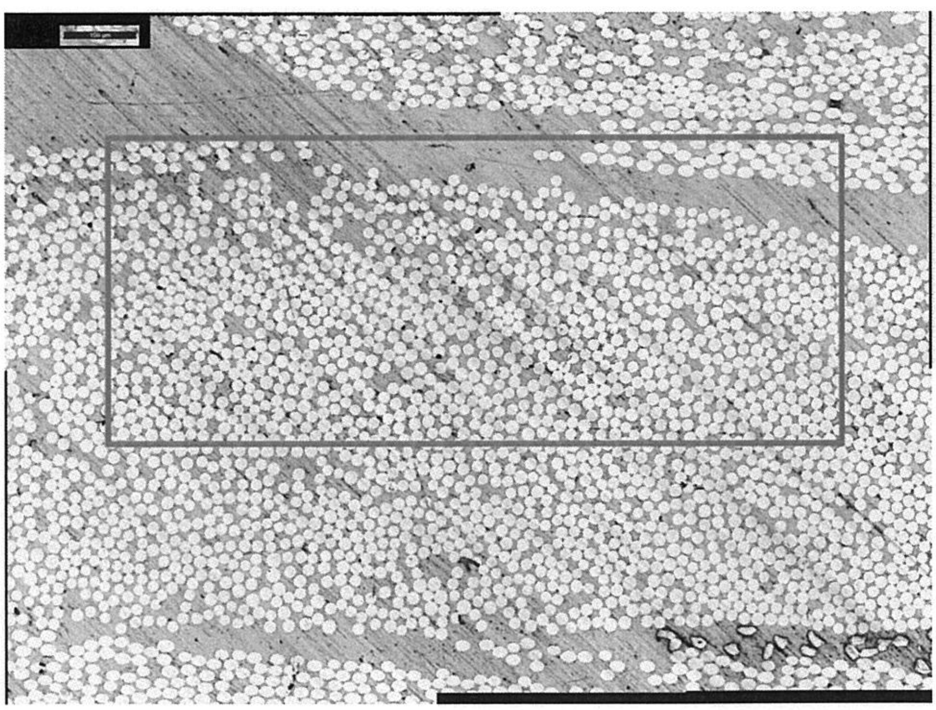
Reinforcement type	Elasticity module [MPa]	Shear module [MPa]	Tensile strength [MPa]	Shear strength [MPa]	Compression strength [MPa]
Woven glass	14352	4728	220	119	96
Woven aramid	19087	2585	357	53	64
Woven carbon	42000	12350	340	180	118
UD glass (0°)	18300	3895	432	30	71
UD glass (90°)	7940	3895	52	30	16

Table 2.5: Tensile Strength ratio of Unidirectional Fiber Reinforced Epoxy (Eksi S. and Genel K., 2016)

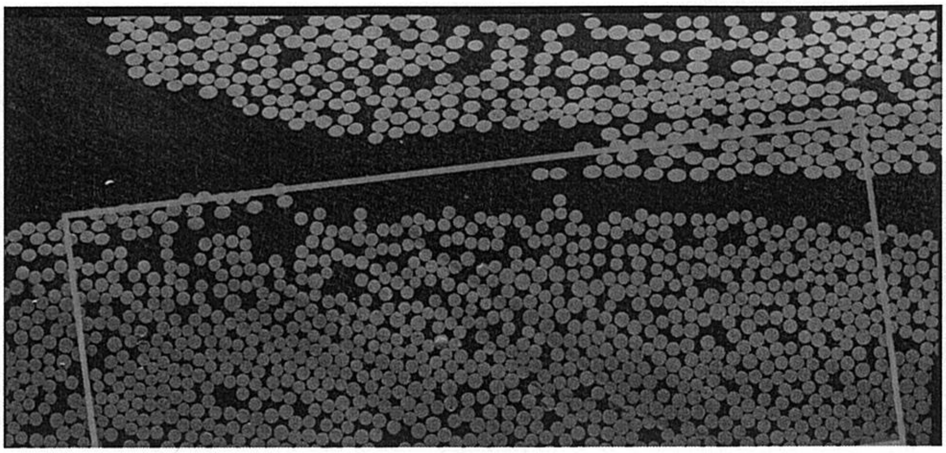
Unidirectional fiber reinforced epoxy	Tensile strength ratio
0° glass / 90° glass	8.3
0° carbon / 0° glass	1.91

From the table, the results obtained from the experiments show that elasticity module, shear and compression strengths of composites with unidirectional carbon fiber reinforced epoxy composite have the best performance, compared to the glass fiber reinforced epoxy composite. On the other hand, tensile strength at 0° orientation of unidirectional glass fiber is 8.3 times higher than that of 90° orientation.

In addition, Monica J. et al. (2018) have undergo multimoidal data set of the unidirectional glass fiber reinforced polymer by scanning at varying resolutions in the micro-scale with several imaging modalities. All scans capture the same region of the sample, containing well-aligned fibers inside a UD load-carrying bundle. The two scans of the cross-sectional surface of the bundle were acquired at a high resolution, by means of scanning electron microscopy (SEM) and optical microscopy (OM) based on Figure 2.1.



(a) Optical microscopy



(b) Scanning electron microscopy

Figure 2.1: Surface scans with the sample area of great overlap across scans marked in green (Monica J. et al., 2018)

The data set obtained, the possiblities to assess the imaging modalities to which a segmentation method is applicable. The quantification of fiber geometry obtained from precise measurements can provide insights into the fiber and composite's manufacturing processes as well as simulating the behaviour of the real sample under load which is useful as it have correation with surface roughness.

2.3 Effect of surface roughness

In order to get a strong and durable joint between composite assemblies, surface treatment is necessary prior to bonding. Several methods to improve the bonding strength of the composite assemblies have been investigated. Niem et al. (1996) studied the joint strength with respect to the surface roughness and surface treatment direction of the adherents. Roizard et al. (2002) investigated the alkaline etching treatment of glass/epoxy composite substrate for micro-scale roughness. Kim and Lee (2004)